DEVELOPMENT OF AN ELECTROPHORETIC IMAGE DISPLAY

QUARTERLY TECHNICAL REPORT

August 1 to October 31, 1980

Sponsored by

DEFENSE ADVANCED RESEARCH PROJECTS AGENCY

DARPA Order No. 3802

Contract No. MDA903-79-C-0439

Principal Investigator: Richard Liebert (914) 762-0300

Monitored by: Dr. Robert E. Kahn

Contract Period: 20 Sept. 1979 - 30 Sept. 1981

Prepared by

PHILIPS LABORATORIES
A Division of North American Philips Corporation
Briarcliff Manor, New York 10510

Novem

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER	2. GOVT ACCESSION NO. AD-A094260
3. RECIPIENT'S CATALOG NUMBER	9
4. TITLE (and Subtitle)	6 DEVELOPMENT OF AN ELECTROPHORETIC IMAGE DISPLAY.
5. TYPE OF REPORT & PERIOD COVERED	Quarterly Technical Report no. 5 Aug~~ust 1 to~~ Octo~~ber 31, 1~~980
6. PERFORMING ORG. REPORT NUMBER	1 -31
7. AUTHOR(s)	10 Richard/Liebert, Joseph/Lalak, Karl/Wittig
8. CONTRACT OR GRANT NUMBER(s)	15 MDA903-79-C-0439, DARPA Order-3802
9. PERFORMING ORGANIZATION NAME AND ADDRESS	PHILIPS LABORATORIES A Division of North American Philips Corp. Briarcliff Manor, New York 10510
10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS	DARPA Order No. 3802
11. CONTROLLING OFFICE NAME AND ADDRESS	Defense Advanced Research Project Agency 1400 Wilson Boulevard Arlington, Virginia 22209
12. REPORT DATE	11 Nov~~ember 1~~980
13. NUMBER OF PAGES	13
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)	12 14
15. SECURITY CLASS. (of this report)	UNCLASSIFIED
15a. DECLASSIFICATION/DOWNGRADING SCHEDULE	

16. DISTRIBUTION STATEMENT (of this Report)

[illegible] RELEASE

[illegible] TED

DTIC ELECTE JAN 29 1981 D C

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

electrophoretic image display
control-grid electrode
ion-beam milling
indium tin oxide (ITO)
indium oxide
matrix-addressed display
sealing
microcomputer
display drive circuits

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The purpose of this work is to develop a 350 x 600 element X-Y addressed electrophoretic image display (EPID). The ion-beam milling process now routinely removes all of the Mylar from the potential wells without destroying the underlying electrode. A number of devices having the 512 character format were fabricated and tested. Interelectrode shorts were found in these displays, and measures are being taken to determine and eliminate their causes. Several of the devices were fabricated with sput-

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

387334

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

20. ABSTRACT (Cont'd.)

tered In_2O_3/ SnO_2 (ITO) grid electrodes; these clearly demonstrated the improved contrast expected by replacing the aluminum grid electrode with an ITO electrode. An evaporation system was set up to deposit In_2O_3. This process is more reproducible than sputtering and gives more transparent films of higher conductivity. Construction of the driver and the interconnection system is complete. The software for the driver has been written. Debugging of the driver and software awaits the availability of a display substantially free of shorts.

PREFACE

This work is being performed by Philips Laboratories, a Division of North American Philips Corporation, Briarcliff Manor, New York under the overall supervision of Dr. Barry Singer, Director, Component and Device Research Group. Mr. Richard Liebert, Metallurgist, is the Program Leader; Mr. Joseph Lalak, Electronic Engineer, is responsible for cell fabrication and technology. Mr. Karl Wittig, Electrical Engineer, is responsible for circuit design; Dr. Howard Sorkin, Organic Chemist, is responsible for electrophoretic suspensions.

This program is sponsored by the Defense Advanced Research Agency (DARPA) and was initiated under Contract No. MDA903-79-C-0439. Dr. Robert E. Kahn is the Contracting Officer's Technical Representative for DARPA.

The work described in this fifth Quarterly Technical Report covers the period from 1 August to 31 October 1980.

SUMMARY

The purpose of this work is to develop a 350 x 600 element X-Y addressed electrophoretic image display (EPID). The ion-beam milling process now routinely removes all of the Mylar from the potential wells without destroying the underlying electrode. A number of devices having the 512 character format were fabricated and tested. Interelectrode shorts were found in these displays, and measures are being taken to determine and eliminate their causes. Several of the devices were fabricated with sputtered In_2O_3/SnO_2 (ITO) grid electrodes; these clearly demonstrated the improved contrast expected by replacing the aluminum grid electrode with an ITO electrode. An evaporation system was set up to deposit In_2O_3. This process is more reproducible than sputtering and gives more transparent films of higher conductivity. Construction of the driver and the interconnection system is complete. The software for the driver has been written. Debugging of the driver and software awaits the availability of a display substantially free of shorts.

TABLE OF CONTENTS

1. INTRODUCTION

Mylar bonding is being routinely performed with good results. Sputter deposition of In_2O_3/SnO_2 (ITO) for transparent electrodes has been used although the sheet resistance is high. Evaporated In_2O_3 is being investigated to replace ITO because of control difficulties with ITO. Ion-beam milling consistently gives clean wells when a thickened underlying conductor is used. Eleven cells were completed and tested. Shorts continue to be a problem. Fabrication of the driver and interconnection system was completed. Debugging of the driver and software will start as soon as a display is available.

A paper entitled "A 512 Character Electrophoretic Display" by R. Liebert, J. Lalak and K. Wittig was presented at the following two conferences: 1980 Biennial Display Research Conf., Cherry Hill, NJ, Oct 21-23, 1980, sponsored by IEEE/SID/AGED; 20th Fall Symposium of the International Conf. on Electronic Imaging, Washington, D.C., Nov 16-20, 1980, sponsored by SPSE.

2. FABRICATION TECHNOLOGY AND TESTING

2.1 Mylar Sealing

Bonding of the Mylar over the row electrodes is being routinely performed, with excellent yield of void-free bonds. To obtain void-free and scratch-free Mylar bonds requires the use of highly polished, aluminum blocks that are clean, scratch-free and dust-free. Since great care must be taken to keep the blocks defect free, hard chrome-plated steel blocks have been ordered to see if this type of pressing block would be less succeptible to damage.

2.2 Deposition of Transparent Electrodes

2.2.1 ITO Deposition

Transparent conductive coatings deposited on glass and Mylar are routinely produced by sputter deposition of an indium/tin target in an argon/oxygen atmosphere. Slight variations of the

deposition parameters are made in order to obtain optimum transparency and conductivity in the coatings. The coatings are highly transparent; though somewhat high in resistivity, they are still acceptable. The sputtering system exhibits an instability that sometimes results in the deposition of an opaque black coating. This black layer is acceptable as a grid electrode on Mylar because it is non-reflective.

ITO is added to the glass in order to thicken the row electrode. This allows for ion beam milling completely through the Mylar and epoxy over the entire substrate, without destroying the row electrode contact. Black ITO layers are obviously unacceptable since the row electrodes must be transparent.

ITO is also deposited on top of the Mylar in order to fabricate transparent conductive column electrodes. A large increase in contrast was obtained when cells were fabricated using transparent ITO instead of aluminum.

2.2.2 Evaporated In_2O_3

Work has started on evaporating a transparent conductive indium oxide layer on the glass and the Mylar. Until now, transparent conductive indium oxide was only obtainable with sputtering or by chemical vapor deposition which required temperatures much too high for the Mylar.

This evaporated coating seems promising. We have been able to obtain 1500 to 3000 Å of indium oxide. The substrate is heated during the evaporation. Initial results indicate that evaporation is a more reproducible way to apply the transparent conductive electrodes than sputtering.

2.3 Ion Beam Milling

2.3.1 Milling Transparent Electrodes

Aluminum is normally used as a mask during the ion beam milling of the Mylar. When ITO or In_2O_3 is used for the grid electrode,

an additional temporary layer of aluminum must be used since the ITO or In_2O_3 lacks the necessary masking ability. To assist in its subsequent removal the aluminum is deposited on a layer of unpatterned photoresist.

Photoresist is spun onto the ITO or indium oxide which coats the Mylar. This photoresist is a barrier between the ITO layer and aluminum. It has been found that this photoresist layer must be well baked to prevent outgassing and subsequent "bubbling" of the aluminum.

Aluminum is evaporated over the photoresist lift-off layer. Care must be taken to evaporate the aluminum slowly in order to prevent spitting from the tungsten heater. A spit is a droplet of aluminum which melts the Mylar, shorting the column electrode to the row electrode below.

When non-reflective black ITO is deposited on top of the Mylar, the photoresist lift-off layer is not required since the aluminum need not be removed. Aluminum is deposited directly on top of the black ITO. In this case, the aluminum is left to aid in contacting the column electrode structure, and the black ITO being non-reflective results in a high contrast image.

2.3.2 Milling the Grid Structure

Ion beam milling has now been developed into a routine process with stable and repeatable removal rates. The milling is accomplished in a 3 inch diameter ion beam miller.

The patterned photoresist is an excellent mask when ion beam milling in 100% argon. An aluminum milling shield is placed over the substrate exposing the column contact fingers, but covering the row-electrode contact fingers. About 10 min. of over-milling of the aluminum is used in order to clean up the top of the photoresist.

Continuing with this same shield, the atmosphere is changed to remove the lift-off photoresist. Without changing the shield,

the atmosphere is changed back to 100% argon to mill the ITO layer. At this point, column-electrode grid and contact fingers have been milled; next, the wells in the Mylar must be formed. To do this, a smaller shield is used which allows milling only in the central area. The atmosphere is changed to 70% oxygen - 30% argon, and the Mylar is milled down to the epoxy. The process of removing all of the epoxy from the bottoms of all the wells also removes about 1500 Å of the row electrodes, but leaving sufficient In_2O_3 to ensure continuity of the row electrodes. When milling is completed, acetone washing dissolves the "lift-off" photoresist which removes the remaining aluminum and reveals the patterned transparent column electrodes.

Because of reports that Polychrome PC-129 is an excellent mask for ion beam milling, an investigation of this material was made. It was found to be equivalent to the AZ1350J now used when an argon atmosphere is used, but did not stand up well when the 70% oxygen - 30% argon atmosphere was used. PC-129 is not a suitable replacement for AZ1350J in the present process and will not be used.

2.4 Device Testing

During this quarter five (5) cells were prepared using evaporated aluminum as the column grid electrode, and six (6) cells were prepared using transparent conducting ITO as the column grid electrode. Also, one sample had black ITO. The improvement in contrast of the cells having the transparent ITO grid electrode over those having the reflective aluminum grid electrode was striking.

2.5 Problems

Our current fabrication procedures seem to be well in hand, but the devices have many shorts and opens. Therefore, investigations have been started to determine and eliminate their causes. Upon careful inspection of the substrates during fabrication, very small cracks in the ITO-on-Mylar coating have

been observed. It is obvious that care must be taken to keep all of the operations as dust-free as possible. Many of the problems could be eliminated if the device were fabricated in a clean room.

Inspection of the masks revealed that some of the above shorts were due to defects in the mask. The mask had been chipped, and there were several locations on the mask where metal was observed to be bridging the isolation lines. The masks were therefore replaced.

3. DRIVE ELECTRONICS

3.1 Driver

Construction of the drive electronics was completed, with the exception of the power supplies. It is now possible to connect the display mounting board to the driver. Debugging of the driver will start as soon as a display substantially free of defects is available.

The software for the 8748 microcomputer which controls the display has been written; it will occupy about one-third of the 1K bytes of program memory available in this device. An Intel MDS system will be used to emulate this software for debugging and to program the EPROM memory in the device when debugging is completed. Since an EPID display nearly free of shorts will be needed for debugging, these two steps have not been performed.

3.2 Packaging

The connection between the display and the printed circuit board is made by using a conductive-elastomer interconnect. The elastomer chosen (#1705 Cho-nector, Chomerics, Doburn, MA.) is 5 mils thick and allows a contact spacing as close as 6 mils. Although the manufacturer's data sheet states that "pressure is not required to develop the latent conductor area", we found that contact could not be made without applying pressure. The pressure is applied by a spider mounted behind the printed

circuit board. Between the spider and the board there is a pressure plate and rubber gasket assembly. Screws in the spider apply pressure to this assembly which in turn compresses the board-elastomer-display sandwich against the rear of the bezel. Using this method, it appears that a reliable contact can be made between the display and the printed circuit board.

4. PLANS FOR NEXT QUARTER

a. Eliminate or substantially reduce the number of shorts.

b. Set up capability to detect shorts early in fabrication.

c. Debug hardware and software for driver.

d. Demonstrate working Phase I device.

e. Select alignment/exposure system for Phase II device.

f. Begin designing Phase II device.

g. Investigate alternatives to ion-beam milling for Phase II device.

DISTRIBUTION LIST

	Copies
Defense Documentation Center Cameron Station Alexandria. Virginia 22314	(12)
Director Defense Advanced Research Projects Agency 1400 Wilson Boulevard Arlington, Virginia 22209 Attn: Program Mgmt.	(2)
Dr. Ben Kazan Xerox Palo Alto Research Center 3333 Coyote Hill Road Palo Alto, California 94304	(1)
Dr. Stephen E. Saunders Information Sciences Institute University of Southern California 4676 Admiralty Way Marina del Rey, California 90291	(1)
James H. Becker Technical Director Exxon Enterprises, Inc. 323 Gibralter Drive Sunnyvale, California 94086	(1)
M. Robert Miller Electronics Research & Development Command Electronics Technology & Device Laboratory DELET-BD Fort Mommouth, New Jersey 07703	(1)